

Abstract

Braille students in grades 4 through 12 were given the task of locating target point symbols and following a tactile track on a tactile pseudomap using a vertical search technique. Half of the 72 students were asked to perform the tasks on a map containing texture (noisy map), while half performed the tasks on an identical map without texture (noise free map). The addition of texture to the map significantly decreased the accuracy of location of points by 20% and significantly increased location time by 36% as compared to the noise free map. It also took the students 41% longer to follow the tactile track on the noisy map as compared to the noise free map. The results are discussed in terms of how texture produces noise and the implications of the results in using texture on tactile maps.

THE EFFECTS OF NOISE ON THE LOCATION OF POINT SYMBOLS
AND TRACKING A LINE ON A TACTILE PSEUDOMAP

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Reading a tactile map is an enormously difficult task for the blind student. Not only is he required to discriminate a substantial number of tactile symbols, but he is also required to scan the display with his fingertips (acquiring information serially) and to code this information to form an organized cognitive map. The blind student's task is complicated further by the lack of a standardized tactile symbology and a dearth of information on tactile map design. Research efforts to date have only produced a small set of discriminable symbols (Gill & James, 1973; Nolan & Morris, 1971; Wiedel & Groves, 1969) which has not been standardized. Furthermore, there has been almost no research on factors affecting map legibility such as the figure ground aspects of a display, the amount of information to be contained on the display, and the effects combinations of symbols have on the legibility of the display.

One way of conceptualizing the tactile map legibility problem is within the context of communication theory. The information to be obtained from a display in the form of symbols or relationships between symbols can be considered the signals, while all additional information or symbols can be considered background noise. Conceptualizing the problem in this way suggests that research should be focused on maximizing the signal strength and/or minimizing tactile noise.

The study being reported investigated the effects of irrelevant information in the form of texture (noise) on the detectability and speed of detecting point symbols on a tactile pseudomap and on the accuracy and speed of tracking a line. Two groups of blind students were given a set of standardized instructions on how to scan a map using a vertical search technique (Berla', 1973). The students were then asked to locate as many of 16 target point symbols on the map as they could during an 8 minute test period. In a second task the students were asked to follow a tactile track on the map as quickly as they could. One group of students was asked to perform these tasks on a map which contained background textures, while a second group performed the same tasks on a map without background textures.

Method

Subjects

The subjects were 38 male and 34 female braille students in grades 4 through 12. Eight students from each of grades 4 through 12 participated in the study. The means and standard deviations of the ages of the students in years according to grade level, are presented in Table 1. The schools that participated in the research were the Ontario School for the Blind, Canada; Overbrook School for the Blind, Pennsylvania; and the West Virginia School for the Blind.

Insert Table 1 about here

Materials

Two tactile pseudomaps were used. They were constructed through a photoengraving process. Male molds were made from this process and copies were made by drape molding styrene plastic over the male molds. Photographic reproductions of the maps are shown in Figures 1 and 2. One map, designated "noisy," had textured areal symbols, line symbols and point symbols. A second map, designated "noise free," had only line and point symbols, but no textured areal symbols. The height of the symbols was as follows: textured areal symbols = .015 inch; line symbols = .025 inch and point symbols = .035 inch. The separation between symbols was .150 inch. The outer dimensions of the maps were 15 x 15 inches. Each map contained 16 target point symbols which were round raised circles having a diameter of .188 inch. On each map there was a tactile track, consisting of a dotted line which began in the lower right-hand corner. The beginning of the track

was designated by an oval point symbol which terminated on the left side at another oval point symbol.

As shown in Figures 1 and 2, a different number was placed next to each target symbol on the original plastic maps so that the experimenters could record the target symbols as the subjects located them. Letters were used to indicate terminal points of track sections. The numbers and letters were not detectable by touch. Additionally, two keys were made. The first key showed one of the round raised target symbols and the second key showed a section of the tactile track which was in the shape of a right angle.

Insert Figures 1 & 2 about here

Design and Procedure

There were two map conditions--noise vs. no noise and two tasks--locating target symbols and tracking. Conditions were randomly assigned to subjects within grades. Half of the subjects within each grade were given the location task first followed by the tracking task and the other half of the subjects were given the reverse order. For the location task each subject was trained to use a vertical scanning technique (Berla', 1973) and given 4 minutes of practice in implementing the strategy. Each subject was presented with a key showing the target symbol that was to be found during the practice and test periods. During the practice period the subject was given feedback to reinforce correct responses and to correct deviations from the accepted pattern. The feedback consisted of reminding the subject to scan straight down the map keeping fingers and hands together and to keep his hands flat on the map. Following the 4 minute practice period the map was removed. The subject was then told that he was to search another map on which he was to locate as many of the target symbols as he could in the time permitted. The same map was presented to the subject

again; however, the map was rotated 180° from the original position. The subject was told to place his hands on one of the upper corners of the map and to begin searching for the target symbols. Task time was measured from the time the experimenter said "begin" until the subject indicated he had searched the entire map. The subject was given a maximum of 8 minutes to complete the task.

For the tracking task the subject was provided with a key having a tactile track in the form of a right angle. The subject was told to use two hands in following the track, one hand behind the other using one or two fingers of each hand. One hand was used to follow the track while the other hand trailed behind and served as a reference. Each subject was then presented with the tactile map and told that he was to follow the track on this map for practice. The subject was shown the starting point of the track and told to follow it to the end. Each subject was given up to 5 minutes to follow the track. At the end of 5 minutes or when the subject completed the tracking task the map was removed, rotated 180° , and given back to the subject as a "different" map. The subject was shown the starting point of the track (which was the end point during the practice period) and was now located on the lower right side and told to follow the track to the end. The experimenter said "begin," and the subject was timed until he followed the track and touched the last section of track designated by the terminal point k as indicated in Figures 1 and 2. The subject received a point for each section of track completed. The maximum number of points a subject could receive was 11. A subject's finger had to trace a section of track from the beginning to the end in order to receive a point. No feedback or instructions were given during the test period.

Results

Scanning

For the scanning task, a two-way analysis of variance for independent groups was performed on the percentage of target symbols located using an arcsin transformation of the data. Grade levels (4-12) and texture vs. no texture constituted the two factors. The analysis showed that texture vs. no texture was the only significant effect ($F = 13.23$, $df = 1,54$; $p < .01$). A summary of the analysis is shown in Table 2. The mean percentage of target symbols located in the no texture condition was 88.19 ($SD = 12.57$) while the mean percentage of target symbols located in the texture condition was 73.78 ($SD = 19.81$). This represents an absolute increase of approximately 15% more target symbols located when the map contained no texture as compared to when the map contained texture and a relative difference in performance of 20%. In addition, the standard deviations indicated that there was substantially greater variability in performance when texture was used on the map than when there was no texture. An F ratio of the variances showed that the texture condition was significantly more variable than the no-texture condition ($F = 2.48$; $df = 30,30$; $p < .01$).

 Insert Table 2 about here

A separate two-way analysis of variance was performed on the task times in seconds using a reciprocal transformation. The only significant effect was for texture vs. no texture ($F = 8.36$; $df = 1,54$; $p < .01$) with the no texture condition being significantly faster than the texture

condition. The mean time in seconds for the no texture condition was 124.06 ($SD = 41.38$) and the mean task time for the texture condition was 168.86 seconds ($SD = 74.92$). The standard deviations indicate that there was substantially greater variability in search time when texture was used as compared to the no texture condition. An F ratio of the variances showed that there was significantly greater variability in search time on the textured map when compared to the no texture map ($F = 3.28$; $df = 30,30$; $p < .01$). A summary of the analysis is shown in Table 3.

 Insert Table 3 about here

Separate nonparametric analyses were carried out on the errors of duplication since the error scores were not normally distributed. In order to assess the effects of texture vs. no texture on the errors of duplication, a Kolmogorov-Smernov two sample test was performed using the small sample formula for a one-tailed test. There was no significant difference between the two conditions ($D = 7$; $N = 36$; $p > .05$). In order to determine whether reliable differences existed between grade levels, a Kruskal-Wallis one way analysis of variance by ranks was performed on the rank order scores of the errors of duplication. There were no significant differences between grade levels ($H = 3.93$, $df = 8$, $p > .05$ corrected for ties).

Tracking Tasks

Only one out of the 36 subjects in the no texture condition, and only 5 out of 36 subjects in the texture condition failed to complete the tracking task perfectly (i.e., followed all sections of the track from

beginning to end). In addition, the maximum number of track sections missed by any subject was two. Consequently, Fischer's exact probability test was used to determine whether the proportion of the subjects who missed sections of track in the no texture condition was significantly different from the proportion of subjects who missed sections of track in the texture condition. There was no significant difference between the two conditions ($p = .099$, one-tail test).

A two-way analysis of variance for independent groups was performed on the total time scores in seconds for the tracking task, using a reciprocal transformation of the data. Grade levels (4-12) and texture vs. no texture constituted the two variables. The only significant effect was attributable to texture vs. no texture ($F = 4.69$; $df = 1,54$; $p < .05$). Following a tactile track on a textured map took significantly longer ($\bar{x} = 77.33$ seconds, $SD = 66.72$) than on a no texture map ($\bar{x} = 54.89$ seconds; $SD = 48.54$). An F ratio of the variances showed that following a line on a textured map resulted in significantly greater variability in tracking time than on the no texture map ($F = 1.89$; $df = 30,30$; $p < .05$). A summary of the analysis is presented in Table 4.

Insert Table 4 about here

Discussion

The addition of textured areal symbols to a tactile map decreased blind students' accuracy of locating target point symbols by 20% and increased location time by 36%. For the line tracking task the addition of textured areal symbols had no effect on accuracy; but substantially increased the tracking time by 41%.

The addition of texture to a tactile map acted as noise in the tactual communication channel. As is well documented in visual and auditory research, as well as vibrotactile research (Geldard, 1972), noise masks a target signal and decreases its detectability. When the fingertips scanned across the display containing texture, it resulted in a certain degree of superfluous stimulation, possibly in the form of vibration. The additional vibration made it less likely for the student to detect a change in stimulation which signaled the presence of a target symbol and thus fewer detections were made. Furthermore, the intensity and frequency of the vibration was in part, dependent upon the speed of the fingertips as they are moved across the map. Students evidently attempted to attenuate the effects of the added noise by reducing the speed of their scanning hand thus increasing the total task time.

For the tracking task students traced the tactile track with their fingertips. Since the tactile track was raised higher than the textured areal symbols, the textured areal symbols could have no effect on tracing performance as long as the fingertips remained on the track. However, when a subject's fingers fell off the track or when the track was interrupted by a break or an additional symbol, it necessitated a

search for the continuation of the track. As the subject searched for the continuation of the track, the fingertips came into contact with a prominent element of one of the textures. Each time this occurred the subject had to make a decision as to whether the element was part of the track (the signal) or irrelevant information (noise). Consequently, each decision required a small, but decided, increment in task time and resulted in substantially longer task times to follow the complete track. Thus, for both tasks, texture had a disruptive effect on performance.

It has been assumed that texture on tactile maps is analagous to the use of color on print maps. However, on print maps color is used in part to enhance the differences between figure and ground as well as to differentiate one adjacent area from another. While texture can be used to differentiate one adjacent area from another, the results of this study showed that it had the opposite effect of making it more difficult to detect figure (point symbols) from ground. Although most producers of tactile displays would agree to limit the amount of irrelevant information on a tactile display, there is a tendency to represent expansive areas (e.g., grass) by a given type of texture thus increasing the general noisiness of the map. Both teachers and producers of tactile maps may want to exhibit caution in the use of texture, particularly in the case where it doesn't serve to differentiate adjacent areas. They may also want to consider differentiating adjacent areas by bounding an area with a line symbol or the use of braille labels instead of textures. Also, it would seem unwise to use texture on areas, where other symbols are needed to represent significant information, as on political maps where capital cities or industrial centers are of major importance.

Another implication of the results is that where line following is the major component of an educational task, such as in reading graphs, the display should be devoid of any prominent texture so that the subject can more efficiently follow the line. The addition of texture would probably increase task time and make tracking more difficult, particularly in the case of interrupted, broken, or crisscrossing lines.

The textured map in the present study was constructed using five different textures. It is reasonable to assume that all five textures were not equally noisy, even though this set of five were highly discriminable. The degree of noise is probably dependent upon the physical dimensions of the elements that made up a texture as well as the spacing and density of its elements. For example, Lederman and Taylor (1972) have shown that the wider the elements and the smaller the spacing between elements in a texture, the greater the subjective estimate of roughness. Consequently, there are probably large differences in degrees of noisiness among any set of discriminable textures. Studies could be performed comparing the noisiness of different textures with a variety of map reading tasks. With this information the designers of maps could not only choose textures that are discriminable, but also provide a minimum of noise.

References

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TABLE 1
Means and Standard Deviations
of Ages in Years According
to Grade Level

Noise Study

	Grade Level								
	4	5	6	7	8	9	10	11	12
$\bar{x}$	11.21	11.83	12.87	14.82	15.34	17.12	18.61	19.39	20.00
σ	1.11	1.25	1.18	1.65	.69	1.27	1.15	1.32	.72

TABLE 2
 Analysis of Variance on Percentage of
 Target Symbols Located Using an
 Arcsin Transformation

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Total	71	13.73070		
Grades	8	.901974	.112747	.66
Texture vs. No Texture	1	2.276516	2.276516	13.23**
Grades X Texture vs. No Texture	8	1.262327	.157791	.92
Error	54	9.289883	.172035	

**p < .01

TABLE 3
 Analysis of Variance on Total Task Time
 in Seconds for Scanning Task Using
 a Reciprocal Transformation

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Total	71	.00082601		
Grades	8	.0001506	.00001882	2.05
Texture vs. No Texture	1	.00007672	.00007672	8.36**
Grades X Texture vs. No Texture	8	.00010313	.00001289	1.40
Error	54	.00049557	.00000918	

**p < .01

TABLE 4
 Analysis of Variance on Total Task Time
 in Seconds for Tracking Task Using
 a Reciprocal Transformation

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>
Total	71	.010270		
Grades	8	.001229	.000154	1.10
Texture vs. No Texture	1	.000654	.000654	4.69*
Grades X Texture vs. No Texture	8	.000862	.000108	.77
Error	54	.007525	.000139	

* $p < .05$

Figure Captions

Figure 1 Noisy pseudomap having texture, line, and point symbols.

Figure 2 Noise-free pseudomap having line and point symbols.



